Chapter 3

Non-Linear Analysis of Heart Rate Variability and ECG Signal Features of Swimmers from NIT-Rourkela: A Case Study

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ABSTRACT

The current study deals with the investigation of the effect of long-term endurance training on the autonomic nervous system of healthy adults. ECG was recorded for 5 min under resting condition in a sitting position using an ECG acquisition device for 25 swimmers and 25 age-matched sedentary controls. Heart Rate Variability (HRV) parameters of the volunteers were used for statistical analysis and classification using binary classification trees and artificial neural networks. The LF/HF ratio for swimmers and sedentary controls was found to be 0.89 ± 0.32 and 0.94 ± 0.46, respectively. This may be attributed to the vagal dominance due to endurance training in the swimmers. Statistical ECG signal processing and db06 wavelet based processing were performed to understand the effect of swimming on the cardiac health. The signal classification results indicated that both the HRV and the processed ECG signal features may be used for the classification of the swimmers and the sedentary controls using CART, Boosted tree, Random Forest and neural network algorithms.

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INTRODUCTION

Recent advances in the biosignal processing techniques allow relating the activity of the autonomic nervous system (ANS) with the cardiovascular mortality, diabetic neuropathy, myocardial infarction and congestive heart failure (Maestri, et al., 2007). Though the efficiency of the ANS may be predicted by performing various biochemical (Richards, et al., 1999), cardiovascular reflex and scintigraphic tests, analysis of ANS activity from the electrocardiogram (ECG)-based non-invasive tests, viz. heart rate variability (HRV), baro-reflex sensitivity, QT interval and heart rate turbulence, are being studied extensively (Katona, McLean, Dighton, & Guz, 1982). Amongst the ECG-based non-invasive tests, the analysis of the HRV is the simplest method to study the sympathovagal balance (Sztajzel, 2004). Continuous HRV monitoring and analysis of the patients may allow the early detection of the above-mentioned diseases, which in turn, help in preventing significant pathophysiological alterations in the patients (Aliberti, et al., 2013).

Athletes have been found to have sinus bradycardia, which may be attributed to the increase in the efficiency of their heart to pump more blood (Ho, Brotherton, Lewis, & Uzunyan, 2014). This helps the sports-persons (e.g. athletes and swimmers) to adapt their body to lack of oxygen during physical strains (Brosnan, et al., 2014). This adaptability of the body have been related to the vagal predominance of the ANS and better synchronization amongst the functioning of the circulatory and the respiratory organs (Aubert, et al., 1996; Baselli, et al.). In the present study, an attempt was made to study the suitability of the parameters obtained from HRV analysis for classifying swimmers from that of sedentary persons.

Few studies have been conducted on the effect of the intensive swimming training in prepubertal swimmers (Vinet, Beck, Nottin, & Obert, 2005), training performance enhancement (Atlaoui, et al., 2007) and variation in performance at different altitudes (Schmitt, et al., 2006). The conclusions derived from these studies could not be generalized because the number of subjects in these studies was less. The present study, therefore, aims to compare the effect of swimming on the HRV and its relationship with ANS in long-term trained swimmers with age-matched sedentary controls.

The calculated HRV features were preliminarily screened using t-test, which analyses the variation in the means of different groups. It is considered as a linear classifier. The significantly different features were identified. Subsequently, Classification and Regression Tree (CART), Boosted Tree (BT) and Random Forest (RF) were used to figure out the importance of each feature during classification. Most of the features used in this study were not normally distributed. In other words, the features had high degrees of variances and were dependent on each other. Such data cannot be classified using traditional statistical classifiers but can be handled by CART (Lewis, 2000). The efficiency of the BT classifier is higher as compared to CART classifier. This may be attributed to the fact that BT classifier prevents the over-fitting of data, thereby, increasing the accuracy of the classifier (Lewicki & Hill, 2006). RF classifier has shown better performance as compared to CART and BT classifiers. It uses a series of decision trees which helps improving the classification efficiency (Rodriguez-Galiano, Ghimire, Rogan, Chica-Olmo, & Rigol-Sanchez, 2012). The important features obtained from the above classifiers were used for further classifications using Artificial Neural Networks (ANN). ANN has been extensively used in medical industry for pattern recognition problems (Cortes & Vapnik, 1995). In addition to this, attempts were also made to analyze the ECG signal using statistical parameters in the time and wavelet domains (Adochiei & David, 2012). Wavelet-based signal decomposition and reconstruction of the signals help